2020 Alaska Seismicity Summary

Technical Report

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1. Abstract

The Alaska Earthquake Center reported about 49,250 seismic events in Alaska and neighboring regions in 2020. The largest earthquake was a magnitude 7.8 event that occurred on July 22 in the Shumagin Islands region. It was followed by about 6,000 aftershocks including a magnitude 7.6 event on October 19. Other active spots include the 2018 M7.1 Anchorage, 2018 M6.4 Kaktovik, 2018 M7.9 Offshore Kodiak aftershock sequences, Purcell Mountains earthquake swarm, and Wright Glacier cluster northeast of Juneau.

2. Introduction

The Earthquake Center reported about 49,250 seismic events in Alaska and nearby regions in 2020 (Figure 1), making it the state's third largest year, after 2018 (about 55,000 seismic events) and 2019 (about 50,000 seismic events) (Figure 2). AEC data analysts also picked and catalogued 1,463,342 seismic phases, once again the third largest number after 2018 and 2019 (Figure 3). The largest and third largest earthquakes worldwide in 2020 were both in Alaska: the July 22 M7.8 Simeonof Earthquake and its M7.6 aftershock on October 19.

Due to various seismic sequences that occurred throughout the year, earthquake detection rates varied from week to week, with the largest peak associated with the October Simeonof sequence, followed by the July sequence, and with the January sequence in the Andreanof Islands being the third highest peak (Figure 4). Throughout the year we averaged 938 reported earthquakes per week, compared with a weekly average of 956 in 2019 and 1,050 in 2018. Between 9 and 30 earthquakes per month were reported felt in Alaskan communities (Figure 5), with magnitudes of these events ranging from as small as 2.1 to as large as 7.8. The largest earthquakes each month ranged from 4.7 in May to 7.8 in July (Figure 5).

There were three notable M6+ earthquakes outside of the Simeonof sequence:

- **M6.2 on January 23 in the Andreanof Islands region, located at 9.6 km depth 80 km W of Adak and 22 km ENE of Tanaga volcano**. Its source mechanism indicates strike-slip faulting, either left-lateral on a N-S striking plane or right-lateral on an E-W striking plane. It was a crustal earthquake, a typical example of crustal faulting events recorded in the region in the past (*Ruppert et al.*, 2012). It was felt in Adak and Atka, with a reported intensity of shaking of IV, light. AEC reported about 700 aftershocks in the first month with magnitudes ranging from 1.0 to 4.3.
- **M6.1 on January 26 in the Andreanof Islands region, located at 4.1 km depth 94 km SE of Amchitka.** Its source mechanism indicates an underthrusting motion consistent with the faulting along the boundary between the subducting Pacific and overriding North American plates. It was felt in Atka, with a reported intensity of shaking of III, weak. AEC reported about 135 aftershocks in the first month with magnitudes ranging from 1.7 to 5.8.
- **M6.4 on December 1 in the Fox Islands region, located at 24.9 km depth 48 km ESE of Nikolsky.** Its source mechanism indicates an underthrusting motion consistent with the faulting along the boundary between the subducting Pacific and overriding North American plates. It was felt in Nikolsky with a reported intensity of shaking of VIII, moderate to heavy, and in Unalaska and Akutak with intensity III, weak. AEC reported about 126 aftershocks in the first month with magnitudes ranging between 1.6 and 4.5.

We continued monitoring a few ongoing aftershock sequences such as the 2018 M7.9 Offshore Kodiak, 2018 M6.4 Kaktovik, 2018 M7.1 Anchorage earthquakes, and earthquake swarms in the Purcell Mountains and northeast Brooks Range. In addition to tectonic earthquake sequences, we recorded about 1,600 glacial quakes and small rock/ice avalanches. See details on these sequences in the following sections and in Table 1.

3. July 22 M7.8 and October 19 M7.6 Simeonof earthquakes

The M7.8 earthquake that occurred on July 21 at 10:12 pm AKDT caused strong ground shaking from Perryville and Sand Point to King Cove and Cold Bay that resulted in damage in several Alaska Peninsula communities. Weak shaking was felt more than 500 miles away in the Mat-Su Valley and Anchorage areas. The mainshock was followed by an active aftershock sequence that culminated in a M7.6 aftershock on October 19. Both earthquakes prompted tsunami evacuations, although fortunately neither triggered significant tsunamis.

These two earthquakes were some of the most scientifically interesting of 2020. In the era of instrumental readings, large earthquakes have occurred along the Aleutian Islands chain, with the exception of the region near the Shumagin Islands (Figure 6). Seismologists have long suspected the “Shumagin Gap” would eventually experience a large earthquake. The July 22 earthquake partially filled this long-recognized seismic gap.

There are some notable differences between the mainshock and its largest aftershock. The July M7.8 earthquake ruptured a 250 km long and 70 km wide section of the megathrust boundary between the subducting Pacific and overriding North American plates. The October rupture zone is much smaller than the M7.8 fault (about 90 km long and 40 km wide) and located farther offshore and closer to the ocean trench where the tectonic plates meet (Figure 7). The M7.6 earthquake had a different source mechanism and was possibly associated with a fault inside the subducting Pacific Plate rather than on the plate interface.

Prior to the October 19, M7.6 event, AEC recorded more than 2,200 aftershocks with the largest aftershocks of M6.1 on July 28 and M6.0 on October 6. The M7.6 earthquake generated its own aftershock sequence, which has produced more aftershocks than the initial M7.8 sequence. Combined we have recorded more than 6,000 aftershocks through the end of the year (Figure 8). Since the M7.6 rupture area extends closer to the land where seismic stations are located, we were able to detect smaller aftershocks than for the M7.6 event located farther offshore. Estimated magnitude of completeness (the value above which we are most likely detecting all earthquakes and below which we lose detection ability) for the M7.8 sequence is Mc=1.6, while it is 2.2 for the M7.6 rupture area (Figure 9). While the rate of the aftershocks has been declining, we expect the Simeonof aftershock sequence to continue through most of 2021, at least.

4. 2018 M7.1 Anchorage aftershock sequence

Aftershocks from the November 30, 2018 M7.1 Anchorage Earthquake continued into their second year at an average pace of about 26 earthquakes per week. Several days of renewed aftershock activity — spurred by a M5.1 aftershock on November 7 — were felt across Anchorage and the Mat-Su Valley. Approximately 1,350 aftershocks were reported for 2020 (Figure 10) with a magnitude of completeness of Mc=1.1, bringing the total count to more than 12,600. About 35 of these aftershocks were reported as felt in 2020. While the original estimates for the duration of this aftershock sequence were on the order of 2-2.5 years (*Michaels et al*., 2019), the seismicity rate remains elevated compared to the background rate prior to the M7.1 earthquake. We expect this sequence to continue at a decreasing rate in 2021.

5. 2018 M6.4 Kaktovik aftershock sequence

We continued to record aftershocks of the 2018 M6.4 Kaktovik Earthquake, the largest earthquake ever recorded on the North Slope. During 2020, we reported about 690 aftershocks (Figure 11) at a magnitude of completeness of Mc=1.3, bringing the sequence up to approximately 6,900. The largest aftershock was M4.1 on April 20. While the 2020 aftershock rate remained at a low rate of about 13 events per week, it is still above the background level and we expect this sequence to continue in 2021.

6. 2018 M7.9 Offshore Kodiak aftershock sequence

We continued to record aftershocks of the 2018 M7.9 Offshore Kodiak Earthquake, a complex strike-slip rupture on a series of conjugate faults and fractures. During 2020, we reported only about 290 earthquakes (Figure 12), bringing the sequence up to approximately 5,200. Due to its offshore location at about 200 km distance to the nearest on-land seismic stations, the magnitude of completeness for this sequence remains rather high at Mc=2.9, The largest aftershock was M5.0 on March 20, with the majority of the aftershocks below M3.5. While the 2020 aftershock rate was low, about 5 events per week, it is still above the background and we expect this sequence to continue in 2021.

7. Purcell Mountains earthquake swarm

The Purcell Mountains swarm, which began in March 2019, turned out to be the second largest contributor to the statewide earthquake total in 2020, after the Simeonof sequence, with about 1,760 events. Although less active than in 2019, it continued at a steady pace of about 34 earthquakes per week (Figure 13), bringing the sequence total to more than 8,400 events. The largest event in the swarm during 2020 was a M5.0 on March 18, with the remainder of the earthquakes below M3.5. We maintained a low completeness level for this sequence at Mc=1.1. A slightly higher rate and lower magnitude of detection were observed in summer months when seismic stations were in a continuous recording mode. To conserve power, northern Alaska stations operate in an on/off regime during winter months, resulting in smaller events (less than M1) not being routinely detected.

8. Northeast Brooks Range earthquake swarm

We continued to monitor seismicity in the northeastern Brooks Range region of Alaska throughout 2020. This region piqued our interest in 2018 and 2019 with swarm-like activity in late summer–early fall months. While there was a slight increase in earthquake occurrence in this region between June and October 2020, it was at a much lower rate than in 2018 (about 2,500 events) or in 2019 (about 1,700 events), and the largest earthquake only measured M3.5

(Figure 14). We recorded about 310 earthquakes in this region in 2020, with a low magnitude of completeness of Mc=1.1 (Figure 15). We will continue to monitor this region in 2021.

9. Glacial seismicity and Wright Glacier cluster

Glacial seismicity is being recorded and studied globally and Alaska is no exception due to its large expanse of glaciated areas. In 2020, we reported about 1,600 glacial quakes, ranging in magnitudes up to M3.4. We normally record the majority of glacial activity near the termini of tidewater glaciers such as in the Prince William Sound region, Icy Bay, and Yakutat Bay (Figure 16). This activity follows seasonal variability and peaks at different times in different areas, with most glacial quakes occurring between April and October (Figure 17). For example, this year most activity in Prince William Sound was recorded in September, April in Icy Bay, September-October in Yakutat Bay, and July-August in Southeast Alaska.

In 2020 an unusual cluster of approximately 350 glacial quakes occurred in July-September under Wright Glacier about 40 miles northeast of Juneau. A few of these events reached magnitudes between 3.0-3.4 and were felt in Juneau. Periodic seismicity in this area has been observed since the 1970s, with event rates usually peaking in summer and early fall. These quakes tend to cluster near the Speel River, where it drains glaciated areas of Mt. Ogden. The levels of activity, however, are not the same every year. Seismicity rates of the July 2020 series, for example, have not been observed since 2011-2012.

References

Ruppert, N. A., Kozyreva, N. P., and Hansen, R. A., Review of crustal seismicity in the Aleutian Arc and implications for arc deformation, *Tectonophysics, V.522-523, pp.150-157,* doi:10.1016/j.tecto.2011.11.024, 2012.

Michael, A. J., et al., Statistical Seismology and Communication of the USGS Operational Aftershock Forecasts for the 30 November 2018 Mw 7.1 Anchorage, Alaska, Earthquake, *Seism. Res. Lett. 91(1)*, doi:10.1785/0220190196, 2019.

Table 1. *Notable Alaska seismic sequences in 2020.*

Name (start date)	Total number of events in 2020	Magnitude of completeness (Mc)	Rate of events per week
Simeonof Earthquakes (7/22 and 10/19/2020)	6,100	1.6 for M7.8 2.2 for M7.6	~200
Purcell Swarm (March 2019)	1,761	1.1	34
Anchorage Earthquake (11/30/2018)	1,350	1.1	26
Kaktovik Earthquake (8/12/2018)	690	1.3	13
Northeast Brooks Range Swarm (July 2018)	310	1.1	6
Offshore Kodiak Earthquake (1/23/2018)	287	2.9	5

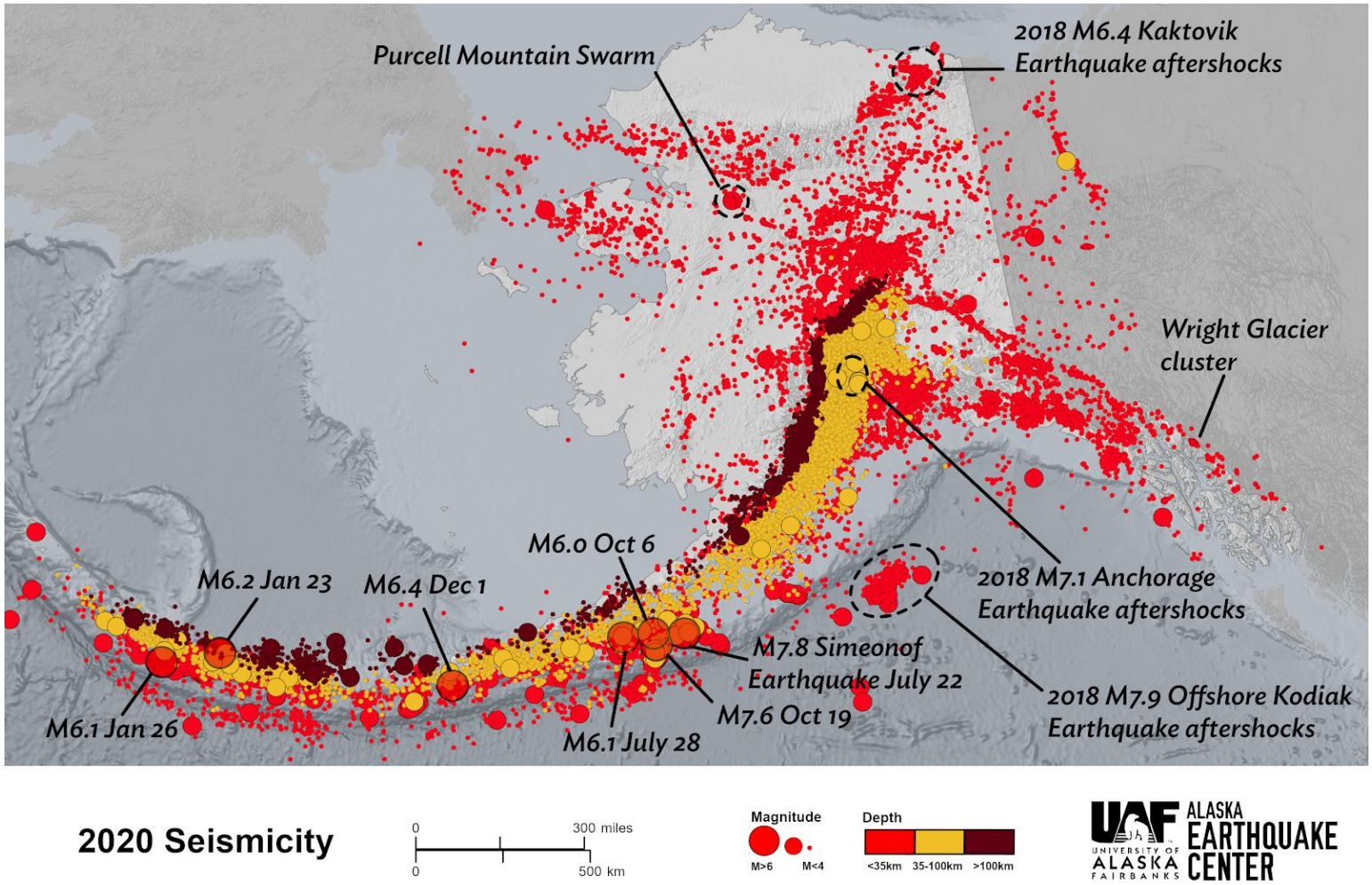

***Figure 1**. 2020 seismicity map.*

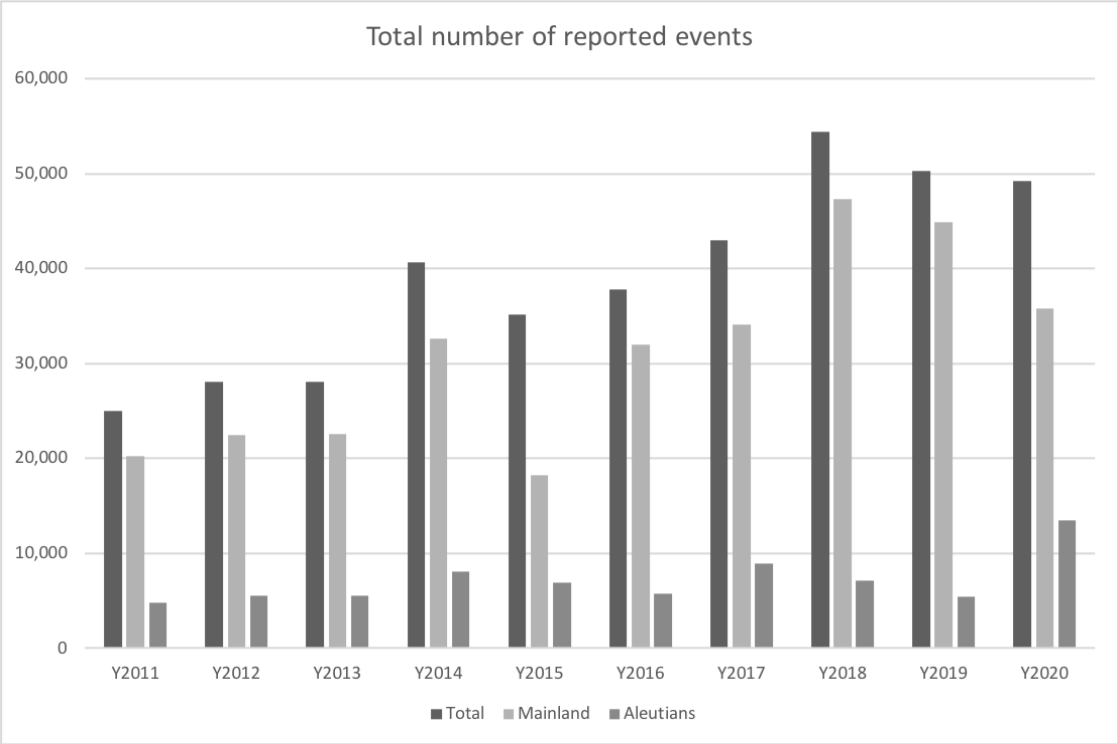

Figure 2. *Earthquakes reported in the Alaska earthquake catalog each year between 2011 and 2020. The total number of events, as well as the number of events in the Aleutians and mainland Alaska are shown. 2018 was the highest year with about 55,000 events, followed by 2019 with about 50,000 events, and 2020 with about 49,000 events. 2020 had more Aleutian events due to the Simeonof earthquake sequence.*

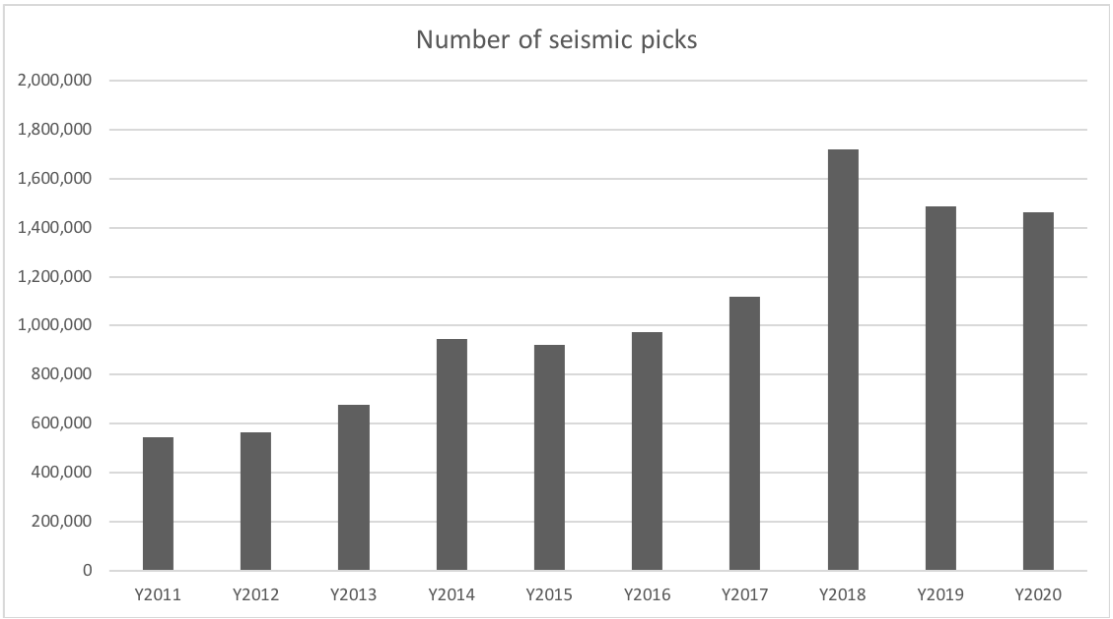

Figure 3. *Seismic phases reported in the Alaska earthquake catalog each year between 2011 and 2020. 2018 was the highest year, followed by 2019 and then by 2020 in 3rd place*.

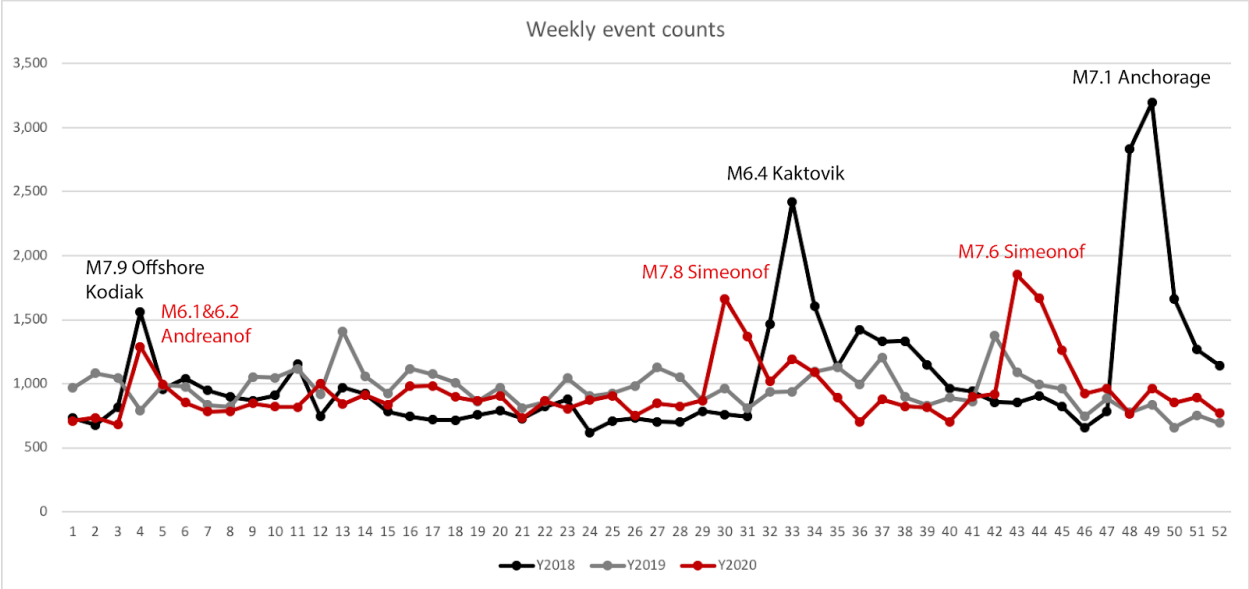

Figure 4. *Weekly earthquake reporting in 2018, 2019, and 2020. Peaks of activity are labeled with a corresponding earthquake sequence.*

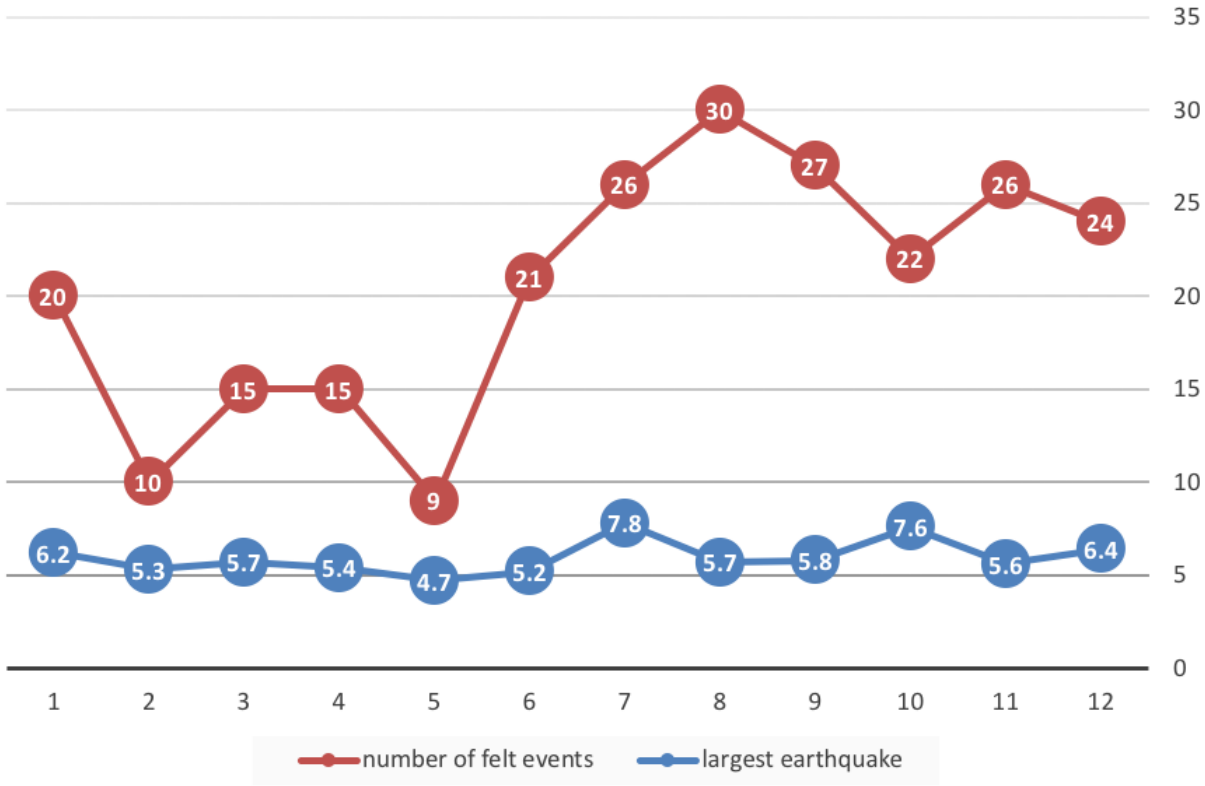

Figure 5. *Largest earthquake recorded (blue line, with magnitude denoted inside a circle) and number of felt events (red line) each month in 2020.*

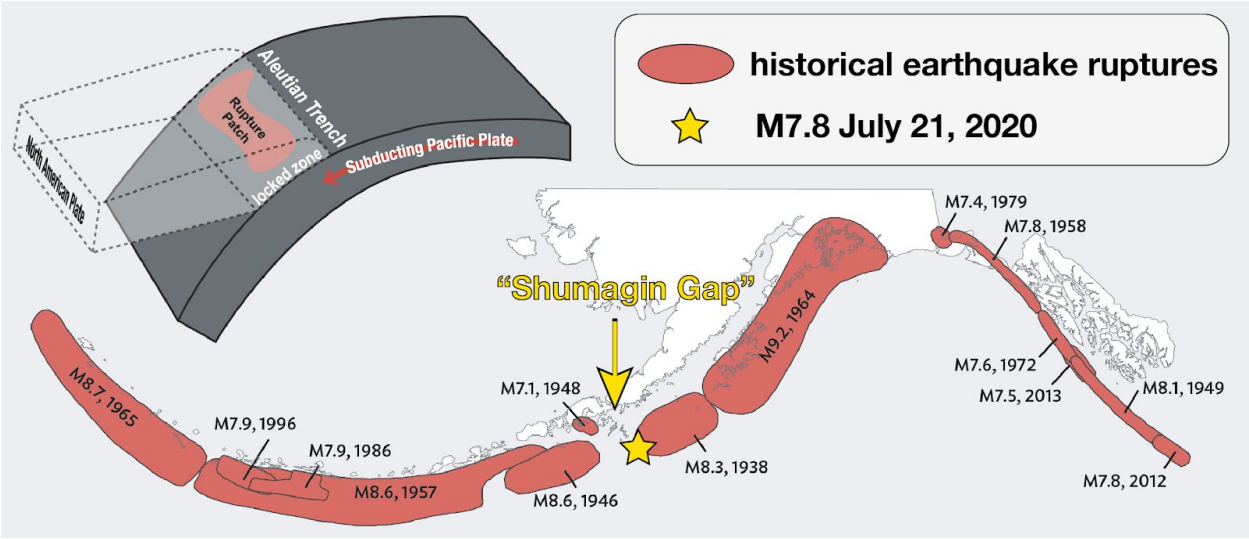

Figure 6. *Major earthquake ruptures along the Alaska-Aleutian subduction zone and the Fairweather-Queen Charlotte fault system. The Shumagin seismic gap was partially filled by the July 22, 2020 M7.8 Simeonof Earthquake.*

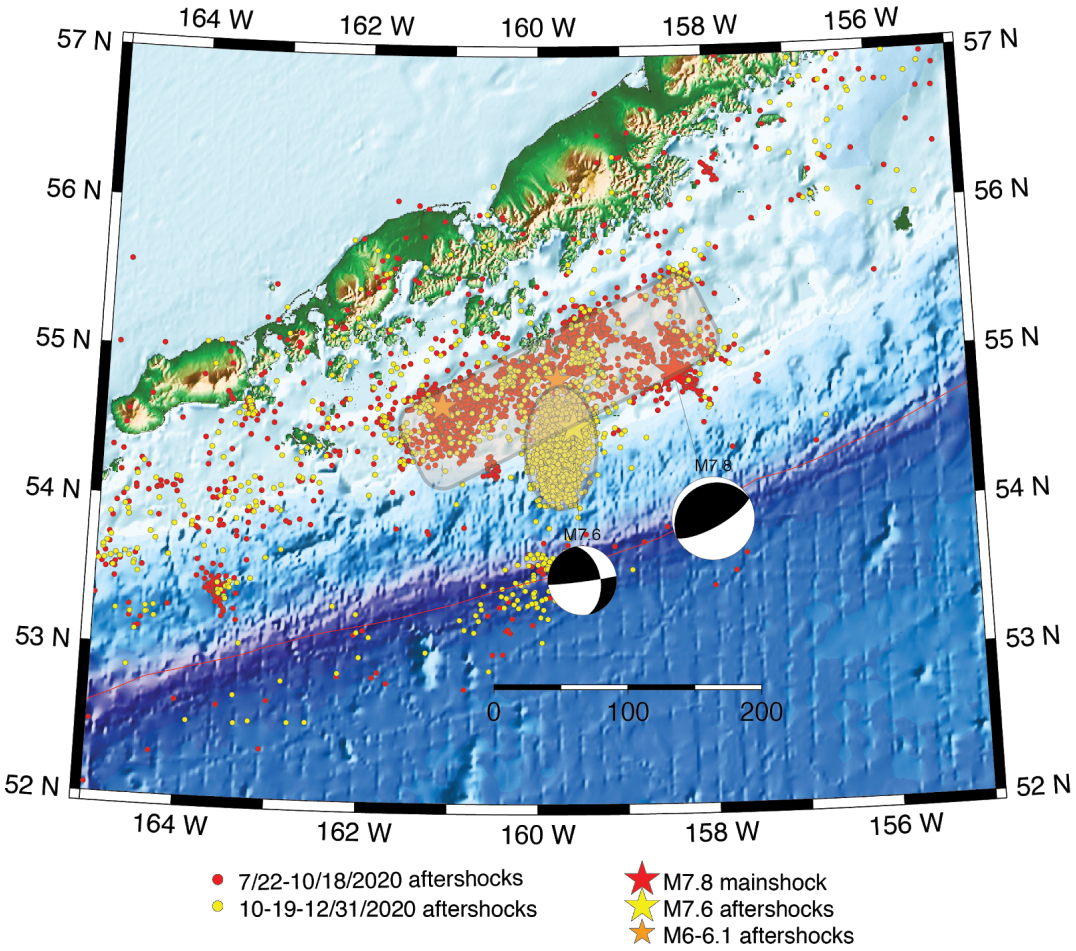

Figure 7. *Location map of the July 22 M7.8 and October 19, 2020 Simeonof earthquakes and their aftershocks. Approximate rupture areas are outlined by the shaded regions.*

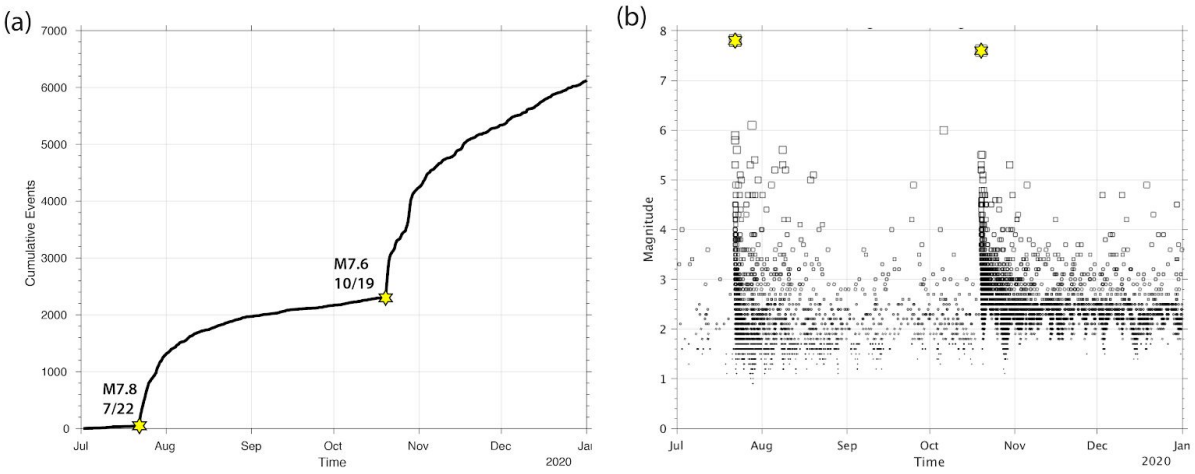

Figure 8. *(a) Cumulative number and (b) time-magnitude plot for the Simeonof earthquake sequence. Note smaller magnitudes detected following the July M7.8 earthquake compared to following the October M7.6 earthquake and higher aftershock rate after the M7.6.*

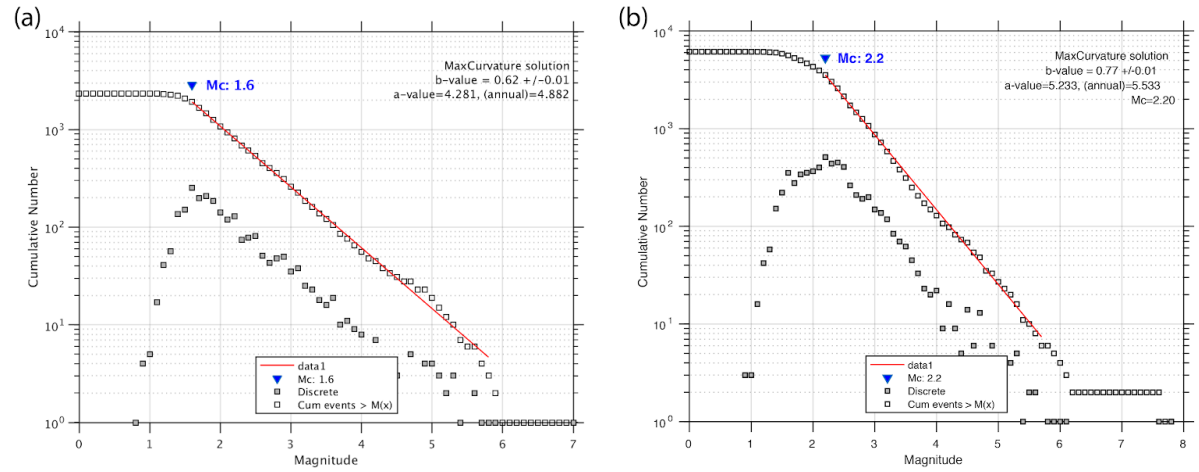

Figure 9. *Frequency-magnitude (or b-value) plots for (a) July 22 M7.8 and (b) October 19 M7.6 Simeonof earthquakes. Note lower magnitude of completeness Mc=1.6 for the M7.8 earthquake compared to Mc=2.2 for the M7.6 event.*

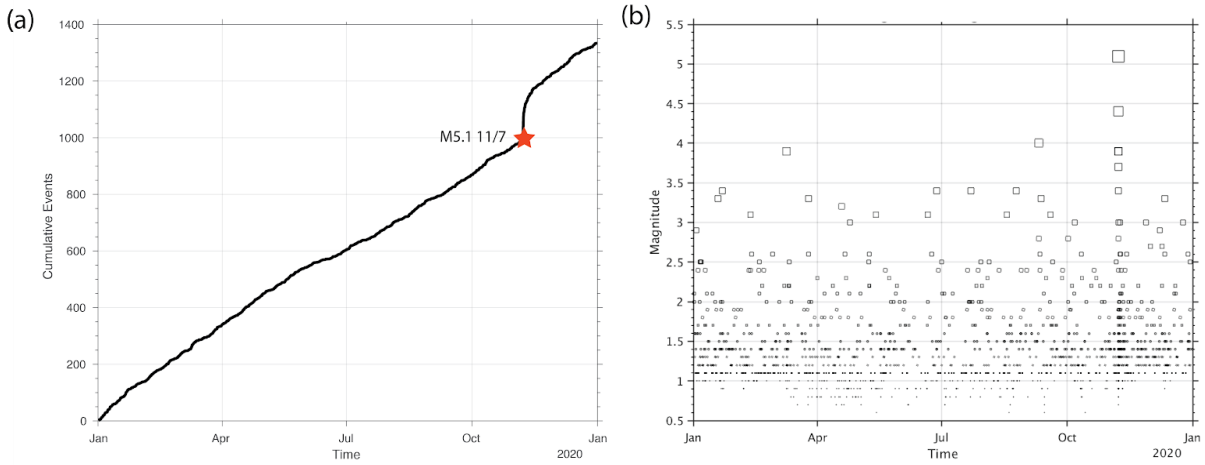

Figure 10. *(a) Cumulative number and (b) time-magnitude plot for the November 30, 2018 M7.1 Anchorage aftershock sequence in 2020.*

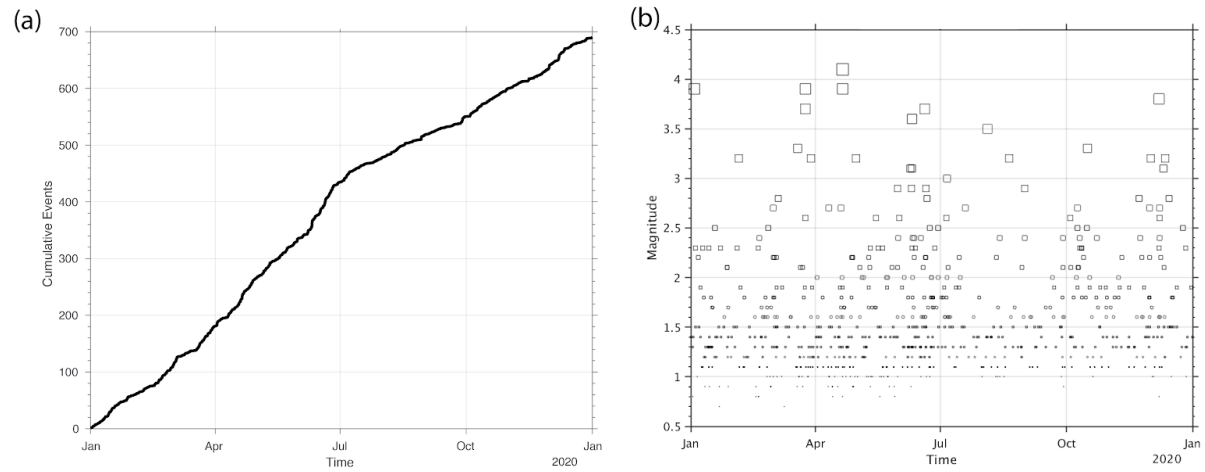

Figure 11. *(a) Cumulative number and (b) time-magnitude plot for the August 12, 2018 Kaktovik aftershock sequence in 2020.*

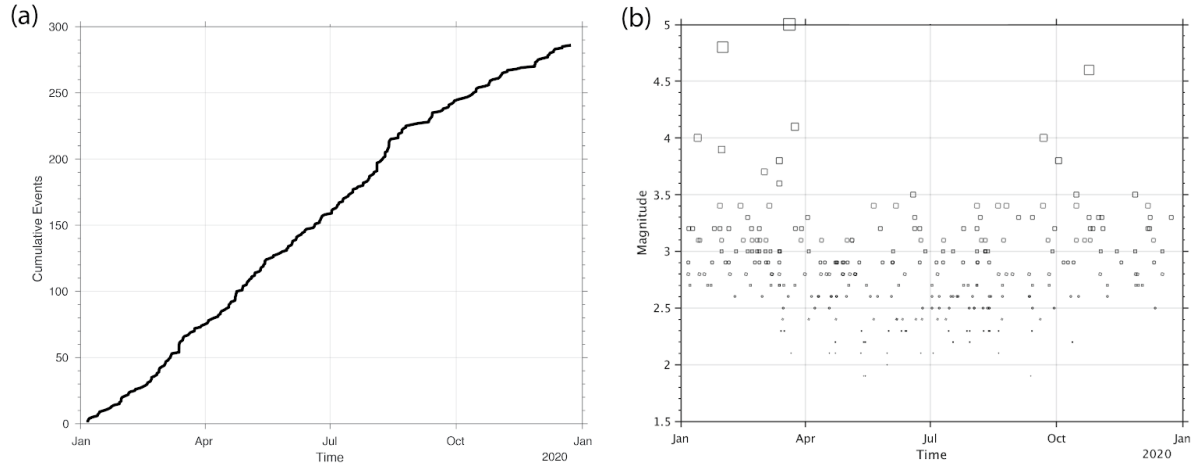

Figure 12. *(a) Cumulative number and (b) time-magnitude plot for the January 23, 2018 M7.9 Offshore Kodiak aftershock sequence in 2020.*

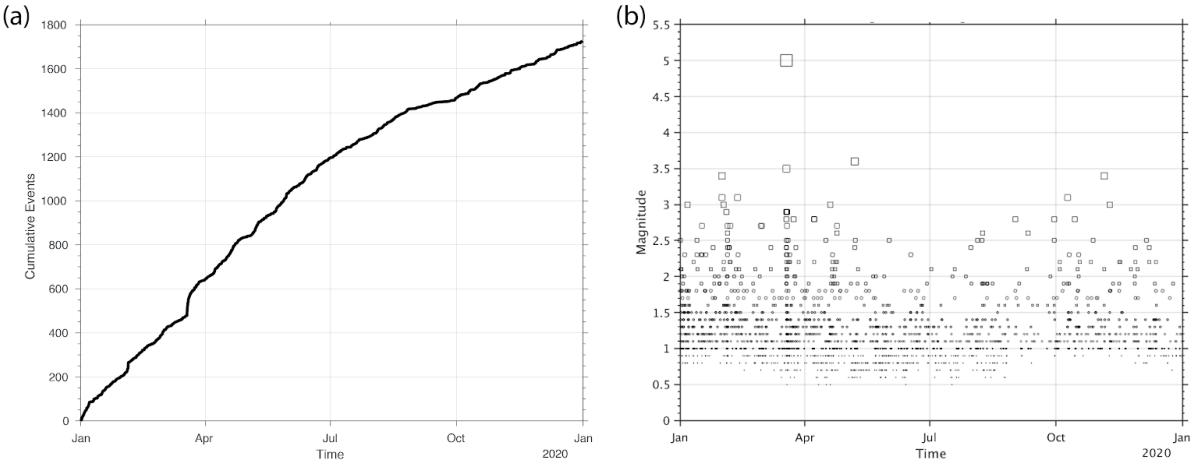

Figure 13. *(a) Cumulative number and (b) time-magnitude plot for the Purcell Mountains swarm in 2020.*

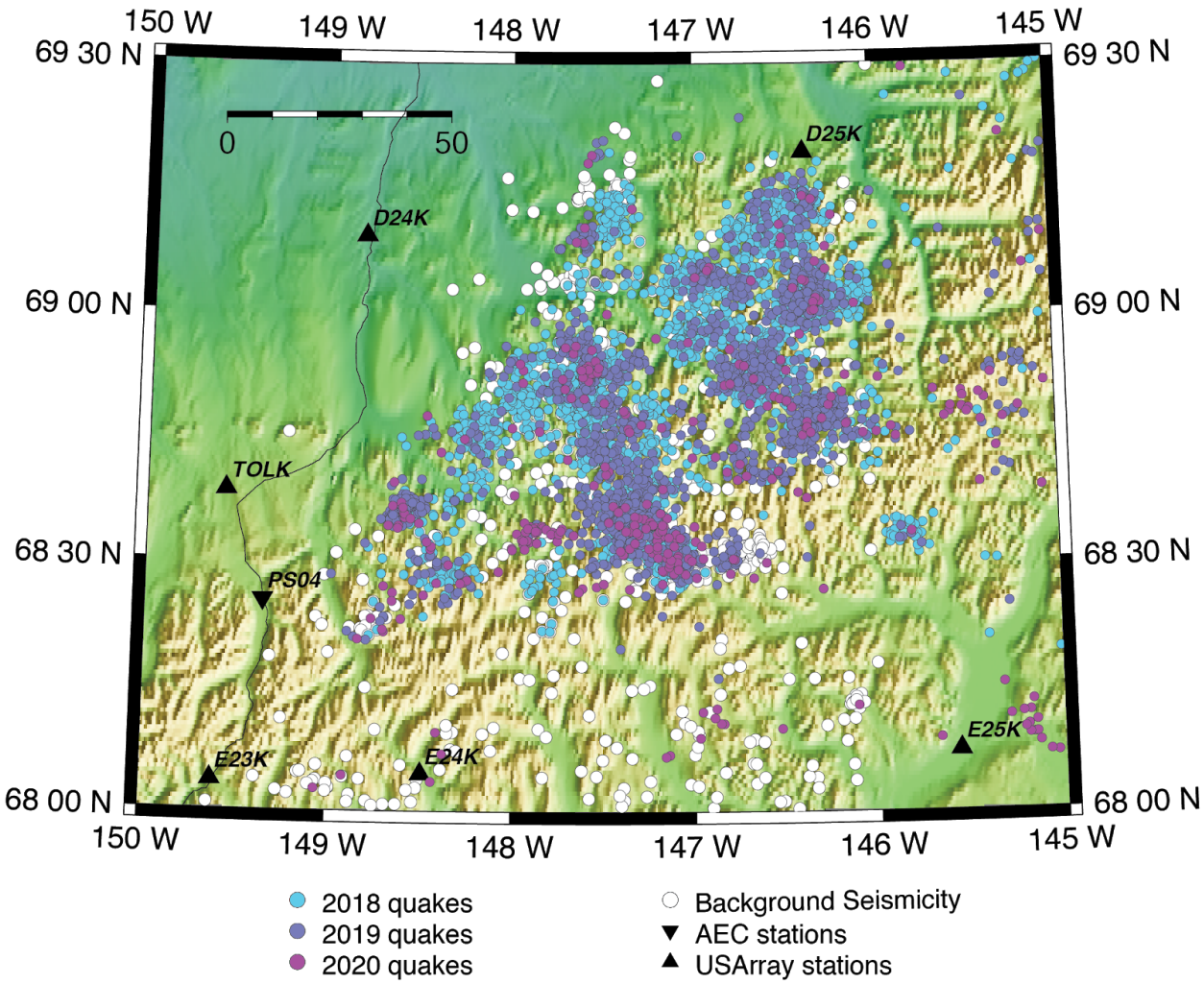

Figure 14. *Location map of the Northeast Brooks Range sequence. It was less active in 2020 than in 2018 or 2019.*

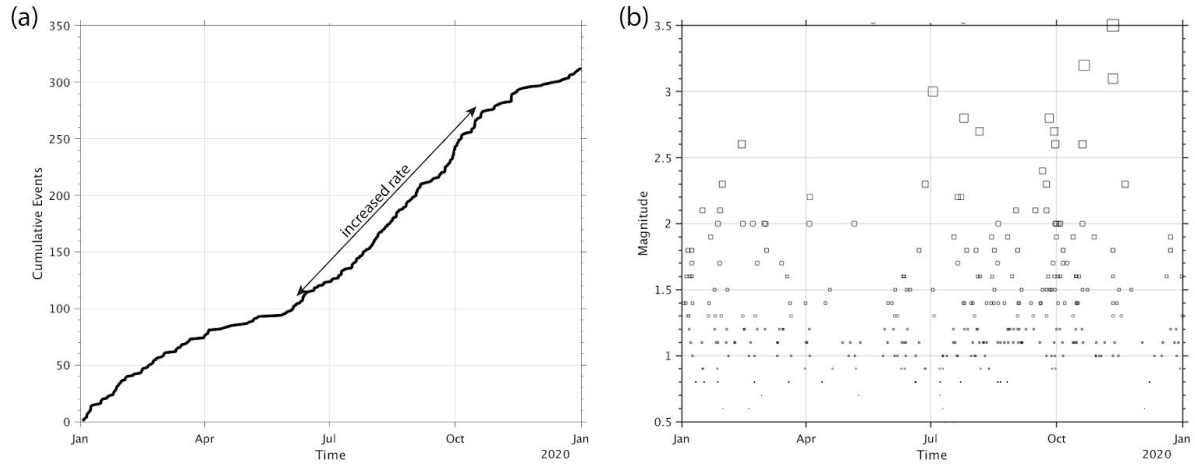

Figure 15. *(a) Cumulative number and (b) time-magnitude plot for the Northeast Brooks Range sequence in 2020. Note slightly increased rate in summer-early fall months.*

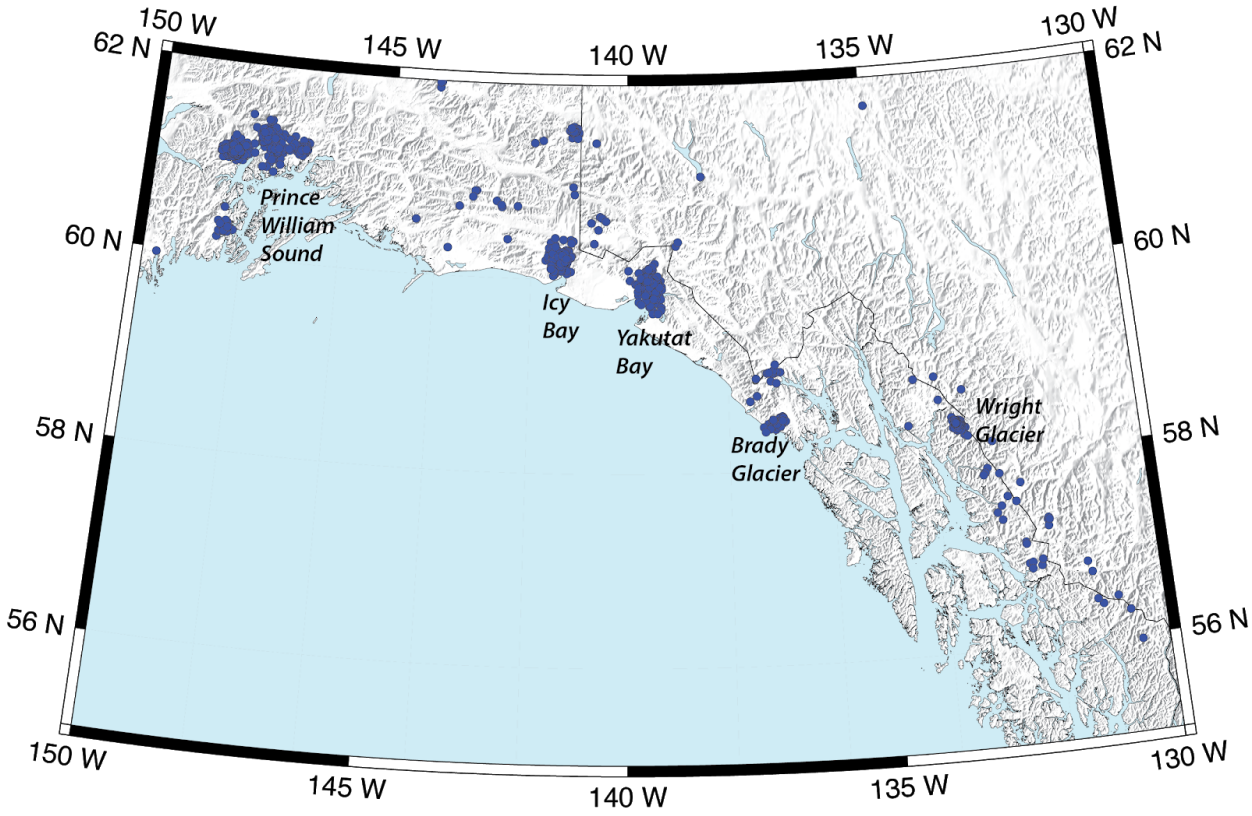

Figure 16. *Glacial events reported in 2020 with the most active areas labeled.*

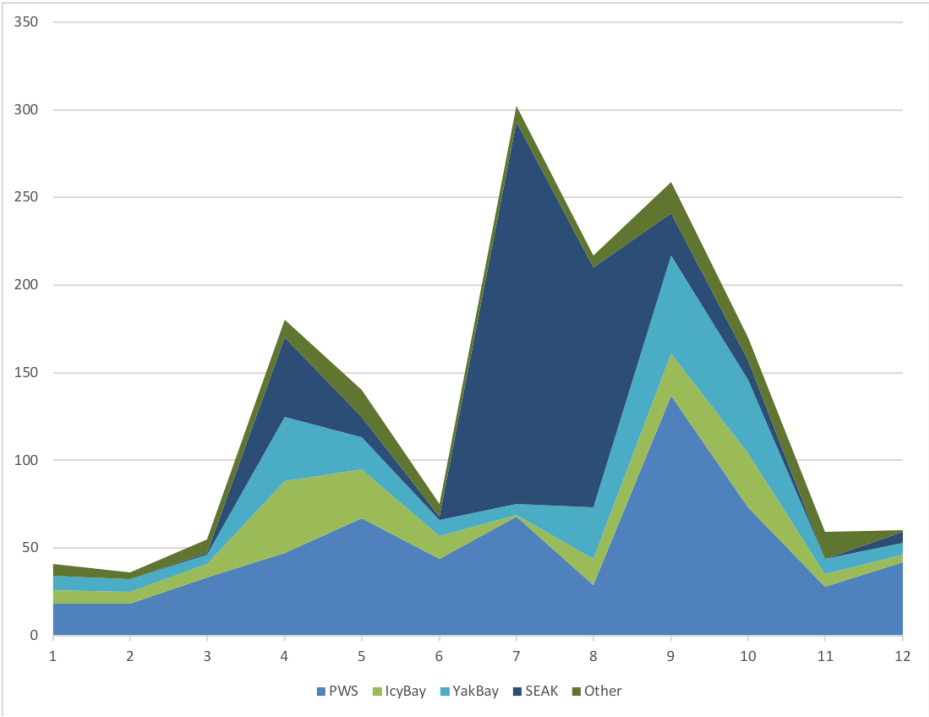

Figure 17. *Monthly counts of reported glacial events broken into 4 main regions of activity. Note that the glacial activity peaked in the April-October time frame.*
PWS - Prince William Sound; YakBay - Yakutat Bay; SEAK - southeast Alaska.